(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 201 263 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86303221.5

(22) Date of filing: 29.04.86

(51) Int. Cl.[4]: E21B 43/20 , E21B 43/01

(30) Priority: 07.05.85 GB 8511468

(43) Date of publication of application: 17.12.86 Bulletin 86/46

(84) Designated Contracting States: DE GB NL

(71) Applicant: MOBIL NORTH SEA LIMITED
Mobil Court 3 Clements Inn
London WC2A 2EB(GB)

(72) Inventor: Burnett, Carl Joseph, Jr.
28 Hartley Road
London NW3(GB)

(74) Representative: West, Alan Harry
Mobil Court 3 Clements Inn
London WC2A 2EB(GB)

(54) Oil recovery method and waterflooding injection system for use therein.

(57) The need for remote surface pumping facilities and associated flowlines is eliminated by locating the pump (6) for seawater injection into a subsea petroleum reservoir, adjacent the seafloor wellhead.

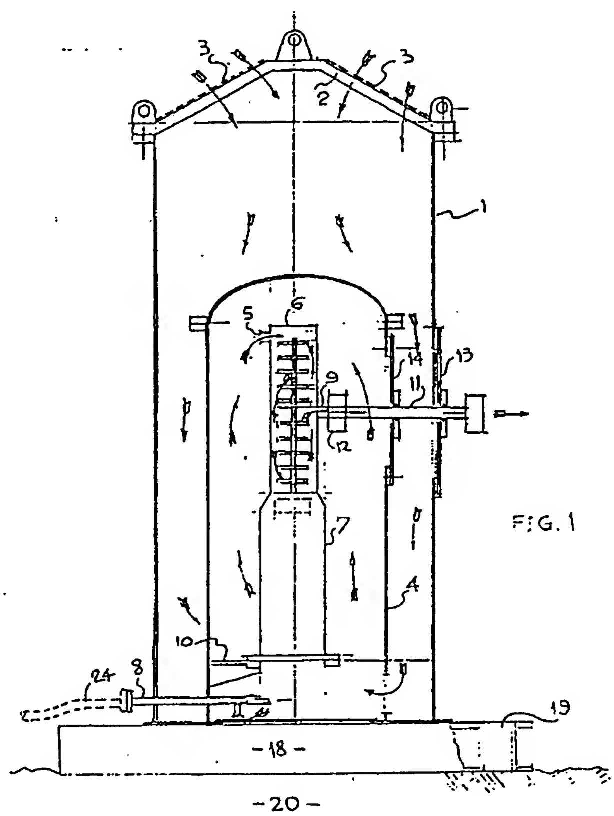

FIG. 1

EP 0 201 263 A1

OIL RECOVERY METHOD AND WATERFLOODING INJECTION SYSTEM FOR USE THEREIN

This invention relates to a method for recovering oil from a submarine oil reservoir and to a system for the injection of seawater into such a reservoir.

Present day techniques for the waterflooding of subsea petroleum reservoirs involve lifting seawater to the surface production facility and then pumping that seawater into the reservoir via a suitable injection system to maintain reservoir pressure and displace oil. The seawater may be de-aerated before being pumped into the injection system to minimize corrosion of wellhead and other equipment.

Quite clearly, the provision of such topside pumping facilities constitutes a very considerable capital investment when the injection/production well is situated at other than a very short distance from the surface production facility. Not only must the required flowlines for produced oil and gas be laid between the wellhead and the surface facility, but also suitable flowlines must be provided for passing the pumped seawater from the surface facility to the injection site. In addition, the vast quantity of seawater that is carried by the surface facility at any one time, together with the pumping and treating equipment for that seawater, add considerably to the weight that must be borne by the surface facility.

The present invention now seeks to eliminate the necessity for remote surface pumping facilities and interconnecting flowlines in subsea waterflooding, by providing a method and system in which a pump located adjacent that subsea wellhead provides the injection water from the seafloor environment.

According to the present invention, there is provided a method for recovering oil from a submarine petroleum-containing formation penetrated by an injection well and a production well in which seawater is injected under pressure into the formation through the injection well and oil is recovered from the formation through the production well, characterised in that the seawater is injected through a pump located adjacent the seafloor injection wellhead.

The provision of the seawater injection pump on the seafloor adjacent the injection wellhead, in contrast to its conventional situation on the production platform at a considerable distance from the injection well, results in a number of important advantages. Firstly, the cost of providing and maintaining a long run of piping connecting the topside pump and the wellhead is elminiated. Secondly, the volume and weight of the pump and its associated equipment and the weight of the water that is in it at any one time is removed from the platform. Thirdly, de-aeration and fine filtering of the water drawn from near the seafloor may not be essential. Other advantages resulting from the method and system of the invention are discussed in detail below.

The invention resides in the use of a seawater injection pump that is located on the seafloor adjacent the injection wellhead. That pump may be electrically or hydraulically driven but is preferably powered by an electric motor which is itself preferably directly coupled to the pump. Quite clearly the pump -and, when the pump is driven by an electric motor, the motor also -must be capable of operating in the submarine environment and are therefore constructed of materials that are highly corrosion resistant and capable of operating for long periods of time without regular maintenance and repair.

The pump is most suitably a multistage centrifugal pump that is capable of delivering up to 2500 m^3 per day (or about 100 m^3 per hour) of seawater at a wellhead pressure of up to 35,000 kPa, although routine operations may require from 1500 to 2400 m^3 per day (65 to 100 m^3 per hour) at a wellhead pressure of 20,000 to 35,000 kPa.

The motor that is preferably used to drive the pump is suitably a high voltage electric motor, for example a 750 kW or 1500 kW motor operating on a 3.3 kV or 6.6 kV, 50 Hz or 60 Hz alternating current supply. The motor is preferably of the water flooded type to eliminate potential sealing problems -especially at the motor-pump junction -and the thrust and journal bearings for the motor are therefore of materials that are suitable for seawater lubrication and cooling, such as elastomeric compositions or ceramics such as silicon carbide. The bearings in the pump are suitably of similar construction.

The electric power for the motor will, of course, be supplied by the surface facility or platform via a suitable high voltage submarine power cable. That cable can be combined with a control umbilical incorporating control lines for the water injection tree and pump system, monitoring lines for pressure and flow readings and, if desired or necessary, small bore tubing for chemical injection.

The pump and motor are suitably directly coupled and mounted on an appropriate base and connected to power, control and monitoring lines and to the wellhead injection system by remotely-operated hydraulic couplings to facilitate removal of the pump/motor unit to the surface for maintenance and/or repair.

It is common practice to de-aearate seawater used for injection on the conventional surface facility but, quite clearly, such a procedure is not possible in the method of the present invention. It is therefore essential that the pump, pipework and well tubulars are constructed of suitably selected materials based on raw seawater duty, as outlined in NACE Recommendation MR-0175, for example. It is not expected that any problem associated with seawater oxygen content will be encountered in the reservoir since the reducing nature of the reservoir environment will rapidly consume dissolved oxygen.

It is, of course, necessary to contain the pump/motor system within a secure enclosure to prevent accidental damage from water-borne debris and to prevent such debris and marine flora and fauna being drawn into the pump along with seawater. Normally, that enclosure will include a coarse-mesh sieve to prevent such ingress although it may be necessary to provide fine mesh filters where the amount of suspended matter exceeds a certain value.

In the North Sea, for example, the total suspended matter (TSM) content of seawater at about 10 m above the seafloor is of the order of 0.4 mg/l. This is somewhat higher than that encountered at greater heights above the seafloor (for example, 0.04 mg/l at 60 m above the seafloor at a location where water is drawn up to a platform for injection pumping), but is still well below the "polished injection water" standard of 2 mg/l TSM. As a result, fine filtration is not believed necessary and formation plugging is not expected to be a problem. However, in locations where the seawater is likely to have a high TSM content, especially shallower waters such as those in the Gulf of Mexico, fine filtration to remove particles larger than 200 um, in diameter, may be necessary to prevent formation plugging problems and to prevent damage to pump and motor bearings.

Raw seawater contains also sulfate reducing bacteria (SRB). If unchecked, these organisms give rise to increasing levels of H_2S in the reservoir. SRB require a reducing environment to multiply - hence injection of non-deaerated seawater will inhibit their growth in the vicinity of the wellbore. Further into the reservoir, however, the removal of free oxygen as described above will lead to reducing conditions which suit the SRB. Some form of biocide injection will therefore be necessary in order to inhibit SRB growth. This may be achieved by providing small bore tubing, for example of stainless steel, within the system control umbilical, to carry biocide to the wellhead. If desired, scale inhibitor can be combined with the biocide.

It is, of course, essential to monitor the volume of seawater injected into the well and this can be achieved by any one of a number of known flow measurement systems. A preferred system utilizes a standard vortex meter mounted in the suction side of the pump. Alternative systems include a magnetic flow meter in the discharge line of the pump, an orifice plate or flow nozzle in the discharge line of the pump and a differential pressure transmitter, and a turbine meter. The vortex meter, magnetic flow meter and turbine meter all generate a frequency signal proportional to the flow, and a generated signal of 4 to 20 mA DC can be transmitted up to about 12 km. Other data transmission systems such as subsea telemetry and fiber optic data transmission can also be used in this respect.

The invention will now be described in greater detail by way of example only with reference to the accompanying drawings, in which

Figure 1 is a diagramatic representation in side elevation of a pump/motor unit in a protective enclosure; and

Figure 2 is a diagramatic representation in side elevation of a system similar to that shown in Figure 1 but including fine filters to remove all but the finest particles.

Referring first to Figure 1 of the drawings, a containment tank 1 is attached via stud bolts (not shown) to a fabricated steel plinth 18 which is itself dowelled to the seabed 20 by piles through holes 19 in the plinth. The conical roof 2 of the tank houses a plurality of sieves of, for example, 6 mm mesh. The mesh should be of a copper alloy to prevent growth of algae. Water flows (as indicated by the arrows) down through the mesh to the bottom of the tank where an inner tank 4 directs the water up towards the inlet 5 of a pump 6. The downward flow followed by the upward flow occurs at such a velocity that unacceptable entrained solids gravitate to the bottom of the tank 1 whence they can be removed.

The elimination of the water contaminated by gravitated particles can be achieved by means of an outlet pipe 8 in which there is an electrically or hydraulically operated pump which is energised periodically, or an ejector continuously energised by high pressure water obtained as a side stream from the discharge of the pump 6. The outlet pipe 8 is flanged to a pipe 24 for conveying the discharged water to a dispersal zone.

The pump 6 is coaxially attached to an electric motor 7, of about 1500 kW running at about 2950 rpm and fed by a 3.3. kV or 6.6 kV supply. The motor is of the water flooded type and of the "solid" type, being either a one-piece forging or of laminar construction, with a final coating of di-electrical material. The casing of the motor is of the same material as the pump, namely, a duplex stainless steel defined generally as of 50 percent austenitic and 50 percent ferritic steel. All other constructional components such as the shaft, screws, keys, washers, bearings, housings, etc., are made of duplex stainless steel with the exception of the rotor which may be constructed of a modified duplex steel or other established magnetic materials used in the construction of electrical machinery.

Stator laminations are of a duplex stainless steel and insulated in a manner similar to that of the rotor. Electrical windings are protected by corrosion resisting materials. Motor and pump may have individual shafts in which case the power is transmitted via a suitable coupling.

The pump is of 10 stages with a co-axial back-to-back impeller array, mounted above the motor. Delivery pressure is attained half way along the shaft and the pump outlet 9 is located in this position. Construction throughout (excepting the rubbing components of bearings) is of duplex stainless steel. The inlet orifice 5 is typically 150 mm in diameter and the delivery orifice 9 is typically 100 mm in diameter.

For support, the combined pump/motor unit may be secured to the inner tank 4 by brackets 10, or suspended from the top of inner tank 4. Outlet nozzle 9 is connected by means of a flange 12 to a delivery pipe 11. Pipe 11 is guided through removable access plates 13 and 14 in the walls of tanks 1 and 4 and sealed to prevent passage of water.

The conical roof 2 serves as a support framework for the sieves 3 and also as a lifting hanger. Bolting unites the framework of roof 2 to tank 1, and after the delivery pipe 11, sludge outlet pipe 8, and any electrical junctions, have been disconnected the whole assembly may be lifted.

Figure 2 illustrates an alternative system for use when filtration of the seawater has to be augmented so that very fine particles, for example, as small as 5 um can be removed. Power driven filters 25 and their driving motors 29 are housed in the containment tank 1. Seawater enters the tank via filtration grids 3 supported on roof framework 2, and enters the filters at inlet ports 26, the filtrate being conveyed to the pump by pipework 27. It is arranged by control valves 28 that one filter at a time can be backflushed by means of independently controlled valves in the auxiliary piping. Filters 25 are disposed peripherally around the inside of tank 1. The remainder of the device is essentially the same as that described above with reference to Figure 1.

The containment tanks 1 of Figures 1 and 2 will generally have a height of up to 12 m and a diameter of up to 4 m. The inner tank 4 shown in Figure 1 may have a diameter of about 2.5 m and a height of about 6.5 m.

Claims

1. A method for recovering oil from a submarine petroleum-containing formation penetrated by an injection well and a production well, in which seawater is injected under pressure into the formation through the injection well and oil is recovered through the production well, characterized in that the seawater is injected through a pump located adjacent the seafloor injection well.

2. A method according to claim 1, wherein the pump is a multistage centrifugal pump.

3. A method according to claim 1 or claim 2, wherein the pump is driven by a motor directly coupled to the pump.

4. A method according to claim 3, wherein the motor is an electric motor.

5. A method according to claim 3 or claim 4, wherein the pump and the motor have bearings that are lubricated by seawater.

6. A method according to any one of claims 1 to 5, wherein the pump and motor are located within a protective enclosure which is attached to the seafloor, and which incorporates a coarse filter for water-borne solid particles.

7. A method according to claim 6, wherein particles passing through the coarse filter are permitted to settle within the protective enclosure.

8. A method according to claim 6, wherein seawater enters the pump through one or more fine filters for water-borne solid particles.

9. A method according to any one of claims 1 to 8, wherein the pump includes means for monitoring the flow of water through the pump.

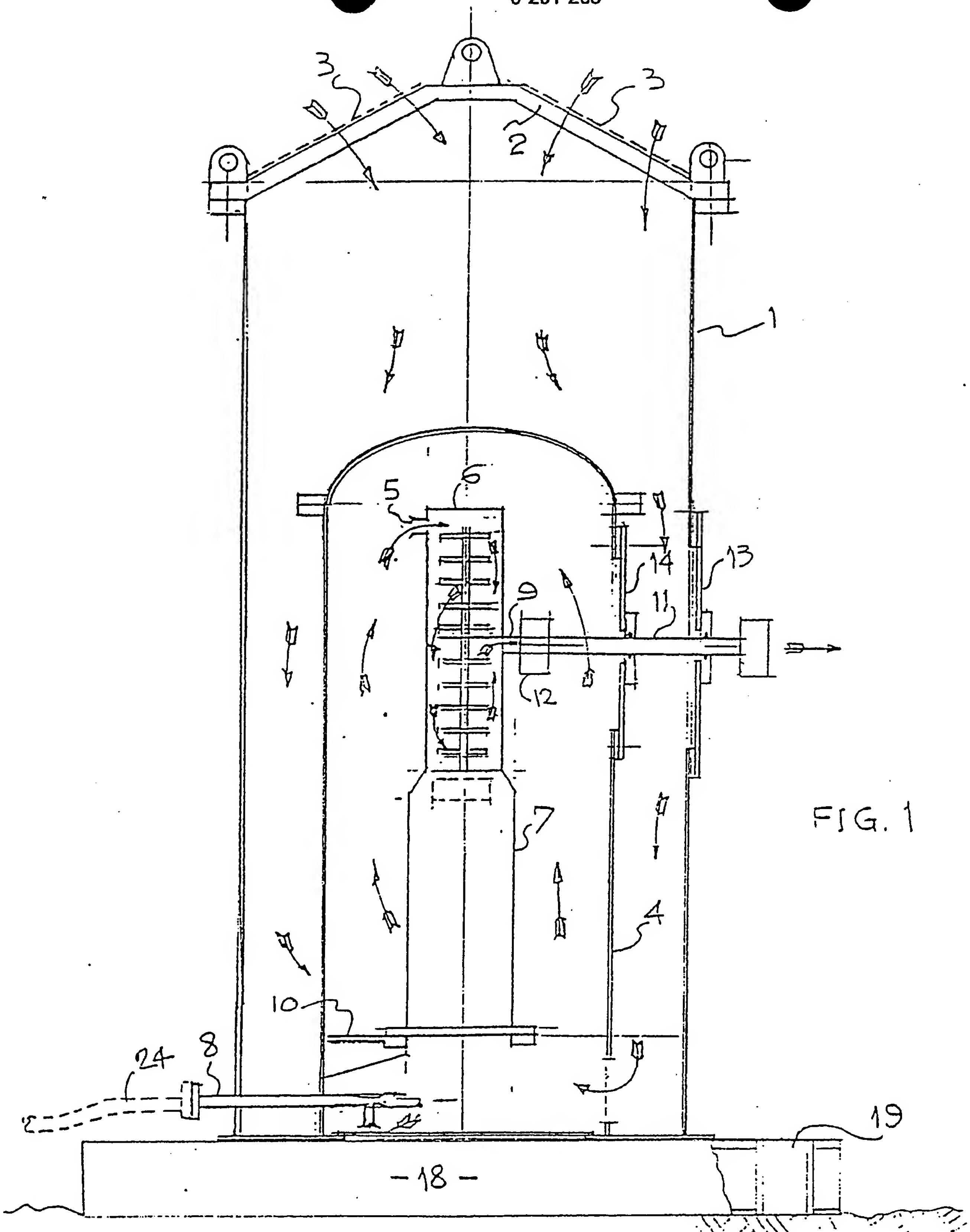

FIG. 1

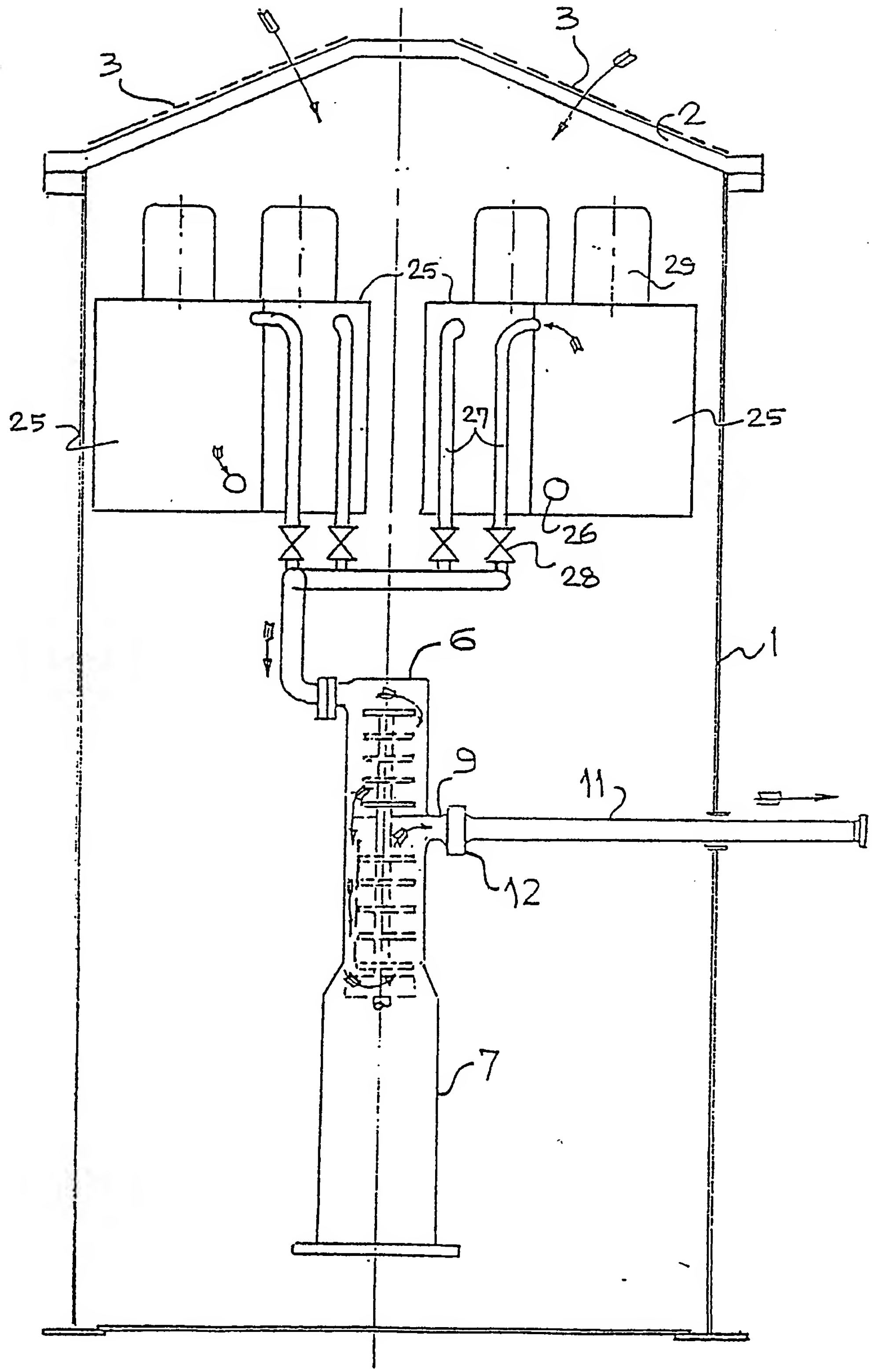

FIG. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 30 3221

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	GB-A-2 067 234 (SHELL INTERNATIONALE RESEACH MAATSCHAPPIJ B.V.) * Figures 1,2; page 1, right-hand column, lines 105-117, 125-126 *	1,3,8	E 21 B 43/20 E 21 B 43/01
Y		2,4,9,5	

Y	THE OIL AND GAS JOURNAL, vol. 74, no. 8, 23th February 1976, pages 99-102, Tulsa, US; R.S. SMITH: " Injection-pump study can cut costs" * Figures 1,4; page 102, columns 2,3 *	2,4,9	
	---		**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
Y	US-A-3 402 670 (BOYD) * Abstract; column 1, lines 21-32 *	5	E 21 B F 04 D

A	OIL & GAS JOURNAL, vol. 75, no. 18, 2nd May 1977, pages 191-195, Tulsa, US; "Packaged water-injection plant aimed at offshore use" * Whole document *	1	
	--- -/-		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	03-07-1986	HEDEMANN,G.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO Form 1503 03 82

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 30 3221

DOCUMENTS CONSIDERED TO BE RELEVANT

Page 2

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	OIL & GAS JOURNAL, vol. 76, no. 19, 8th May 1978, pages 167-170, Tulsa, US; A. FRANCO: "Miniplants speed projects, slash costs" * Whole document * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	03-07-1986	HEDEMANN, G.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO Form 1503 03 82